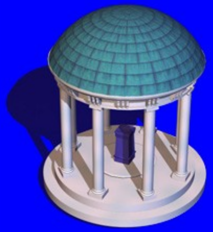


The Design of Design

Fred Brooks

University of North Carolina at Chapel Hill

brooks@cs.unc.edu

Desi gn

“To form a plan or scheme of,

to arrange or conceive in the mind...

for later execution.”

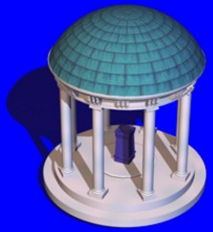
Oxford English Dictionary

W.A. Mozart

"Everything has been composed,

just not yet written down."

Letter to Leopold Mozart, 1780



Why Study the Design Process?

- Can I design better by looking at design process?
- Can we better teach others to design?
- Can we better organize and manage design?

- Let’s limit ourselves to the design of systems

Sir Francis Bacon’s Reason

- New ideas would come about “by a connexion and transferring of the observations of one Arte, to the uses of another, when the experience of several misteries shall fall under consideration of one mans minde.”

  The Two Books of the Proficience and Advancement of Learning, Book 2, p 10, 1605

- **Design process studied in architecture, mechanical engineering, and industrial design.**

- **What can we learn from them?**

21st Century Design Issues

I. Models of the design process

II. Collaborative teams and solo/chief designers

III. How to get *great* designs

I. How Engineers Think of Design

- Goal
- Desiderata
- (Non-linear) utility function
- Constraints, especially budget (not necessaril
- Design tree of decisions

```
UNTIL (design is "good enough") or (time has ru
   DO another design (to improve utility function
      UNTIL design is complete
         WHILE design remains feasible,
            make another design decision
         END WHILE
         Backtrack up design tree
         Explore a path not searched before
      END UNTIL
   END DO
   Take best design
END UNTIL
```

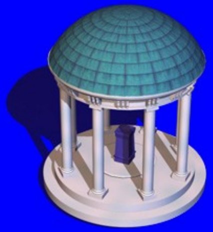
What's Wrong with This Model?—1

- **We don't really know the goal at first –**
  - **The hardest part of design is deciding *what* to design.**
  - **Often the most important function of the designer is helping the client decide what he wants.**

What's Wrong with This Model?—1

- We don't really know the goal at first –

- Here is where experts go wrong:
  - Miss fresh vision – e.g., minicomputer, microcomputer
  - Vision not high enough – e.g., OS/360 JCL

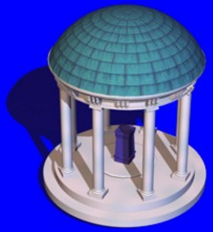


OS/360 JCL – the Worst Language

- Done under my management

- One job language for all programming languages
- Like Assembler language, rather than PL/I, etc.
- But not exactly like Assembler
- Card-column dependent
- Too few verbs
- Declarations do verbish things, in the guise of pa
- Awkward branching
- No clean iteration
- No clean subroutine call

- Basic problem was pedestrian vision
  - We did not see it as a schedule-time program at all, but as a "few control cards"
  - It was not *designed,* it just grew as needs ap



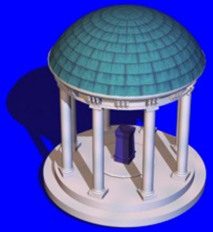
What's Wrong with This Model?—2

- **The desiderata and their weightings keep**
  - **Donald Schön – ”as one wrestles with the probl**
  - **As one in fact *makes* the trade-offs, the weight**
  - **Sometimes one hits new opportunities.**

What's Wrong with This Model?—2

- The desiderata and their weightings keep

- We usually don't know the design tr

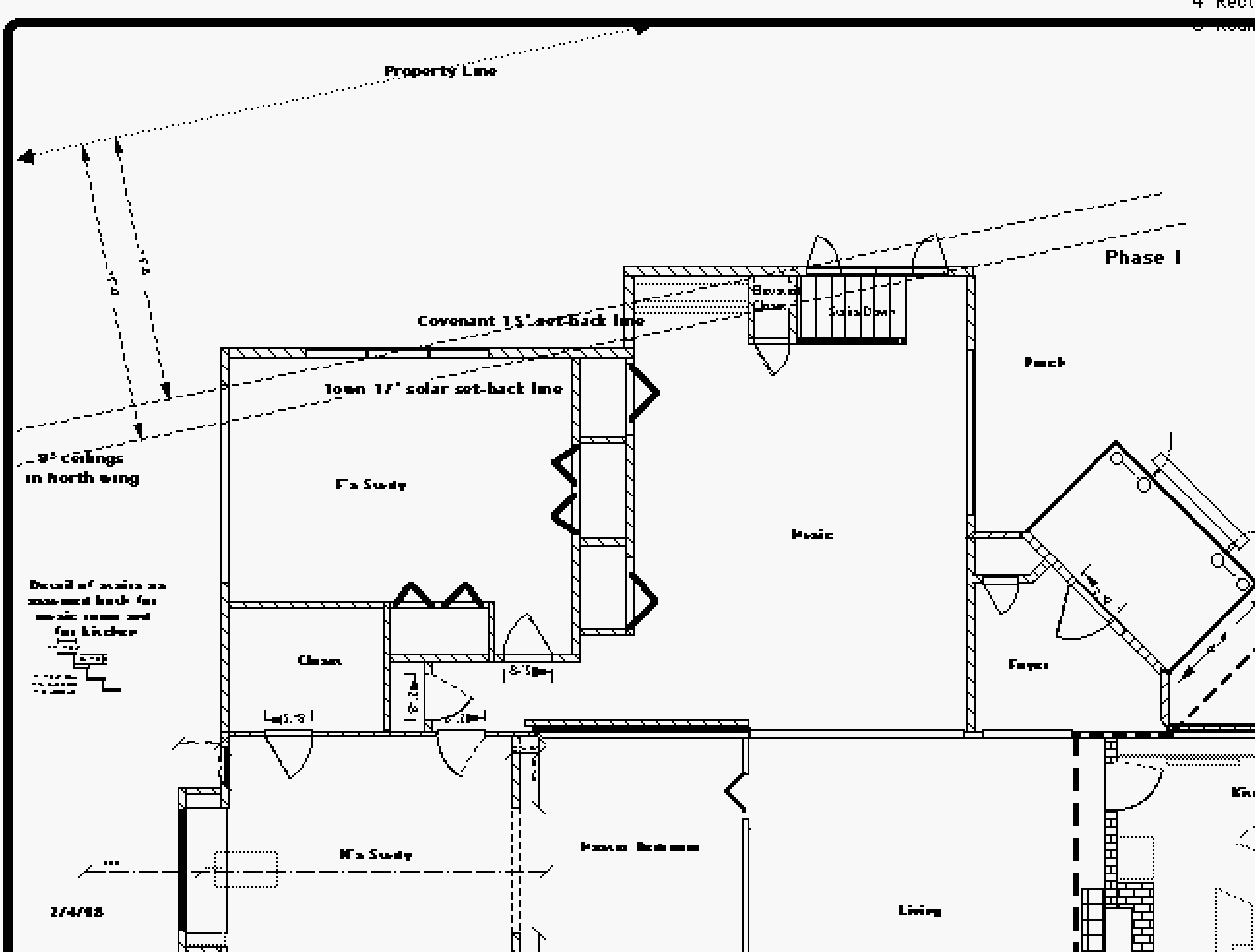


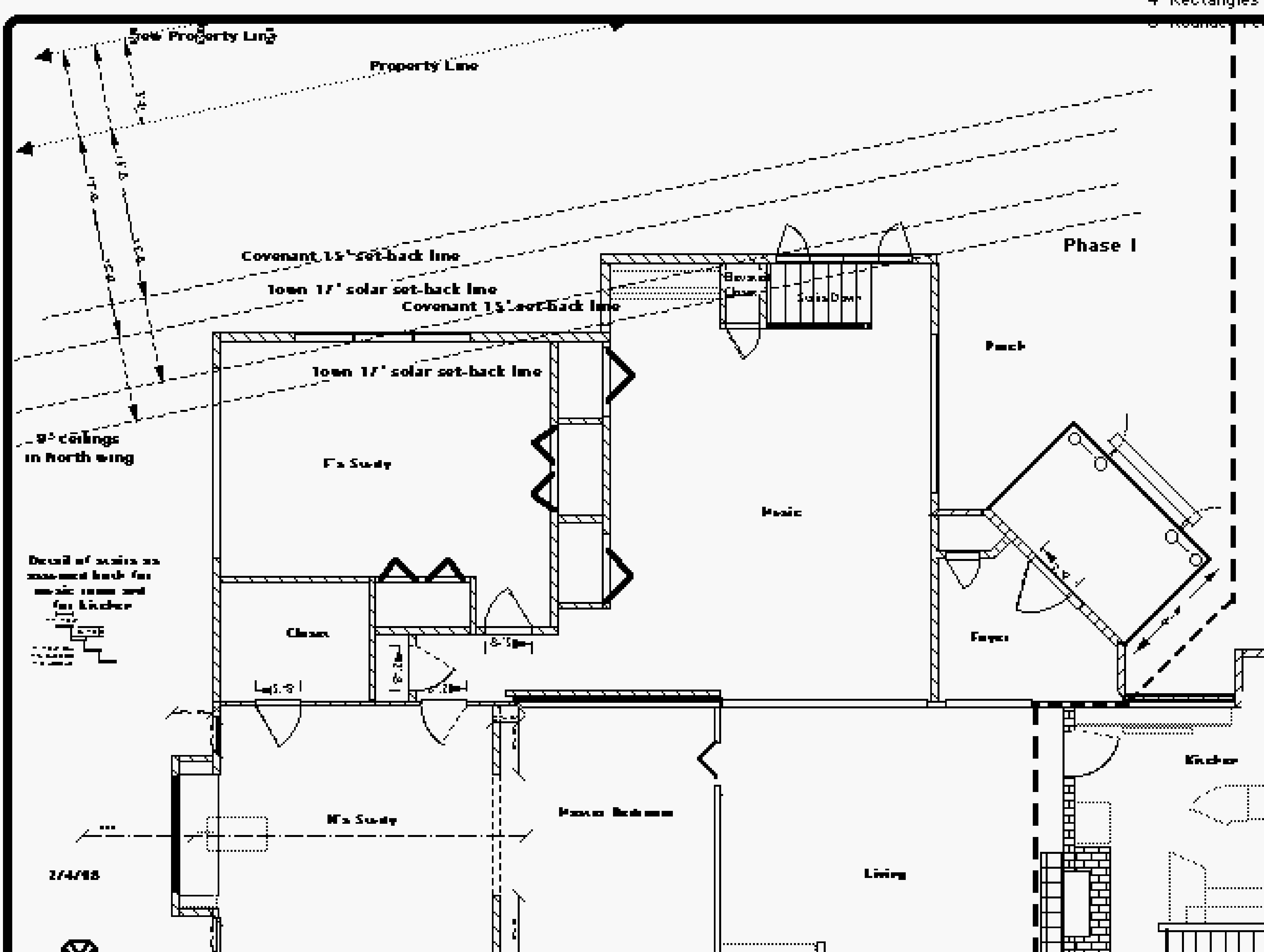
What's Wrong with This Model?—2

- The desiderata and their weightings keep

- We usually don't know the design tree.

- The constraints keep changing.
  - Often by the ever-changing world.
    - Sometimes by total systems thinking, outside the box!


Property Line
Phase I
Covenant 15' set-back line
Town 17' solar set-back line
9' ceilings in north wing
Board Close
Stairs Down
Porch
E's Study
Music
Closet
Foyer
Detail of stairs as stepped back for music room and for kitchen
M's Study
Master Bedroom
Living
2/4/08



Sew Property Line
Property Line
Covenant 15' set-back line
Town 17' solar set-back line
Covenant 15' set-back line
Town 17' solar set-back line
Phase I
9' ceilings in North wing
Broom Closet
Stairs Down
Porch
E's Study
Music
Detail of stairs as [illegible] back for music room and for kitchen
Closet
Foyer
Kitchen
M's Study
Master Bedroom
Living
2/4/08

Design Models

- The rational model is wrong—doesn't describe what really goes on
  - But still the "consensus model" in engineering literature.
  - See for example, G.Pahl and W. Beitz, 1984 *Engineering Design: A Systematic Approach*

Design Models

- The rational model is wrong—doesn’t describe what really goes on

- Most expert designers don’t work that way

Design Models

- The rational model is wrong—doesn’t describe what really goes on
- Most expert designers don’t work that way
- It can give bizarre results
  - LHX helicopter functional specs

Design Models

- The rational model is wrong—doesn’t describe what really goes on
- Most expert designers don’t work that way
- It can give bizarre results
- We have such a model in software engineering

The Waterfall Model is Dead Wrong

- Not how we buy a new building, or a new airplane
  - We pay for a *design phase,* approve a design, and contract for its implementation, or
  - A builder pays for a design phase, sells implementations

The Waterfall Model is Dead Wrong

- Not how we buy a new building, or a new airplane

- Based on spurious assumption that function and performance are what matters about software.
  - A naive notion from early days
  - Reliability, changeability, structure, testability

A Better Model —Co-evolution

- Model due to Maher, Cross
- The effective problem space evolves as the solution space evolves by being explored.

$$\begin{tikzcd}
P1 \arrow[rr] \arrow[dr] & & P2 \arrow[rr] \arrow[dr] & & {} \\
& S1 \arrow[ur] \arrow[rr] & & S2 \arrow[r] & {}
\end{tikzcd}$$

Evolutionary Software Development

1. Build a minimal working system.
2. Try it with real users.
3. Revise.
4. Add function in small increments.

- Robust under changing desiderata and co
- Early testing exposes our inevitable mista

II. Solo Design and Collaboration

- The design *team* is the 20th-century novelty.

- *Conceptual integrity* is the problem with this —
  hard!

- Design as "interdisciplinary negotiation"? NO!

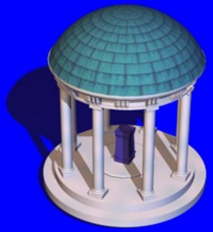
- Mills' chief-programmer concept —

A System Architect

- A ***system architect,***
  for designs beyond one chief designer

- **The architect:**
  agent, approver, advocate for the *user*

- **Detailed: Chapters 3-6 in**
  The Mythical Man-Month



The Cathedral and the Bazaar

- Raymond’s brilliant essays on Linux’s process
- The bazaar is an evolutionary model
  - No committee design —
    each piece has conceptual integrity
  - Emphasizes early and *large-scale* testing
  - Marshalls many minds for fixing, not just testing
  - The market votes by adoption among alternatives
- Based on a gift <—> prestige culture

The Cathedral and the Bazaar

- Raymond’s brilliant essays on Linux’s process
- The bazaar is an evolutionary model
- Based on a gift <—> prestige culture

- Among people who are fed anyway
- Works when the builders are the clients
  - Know requirements from personal experience

- Is this how to do an air traffic control system?

Collaboration and Telecollaboration

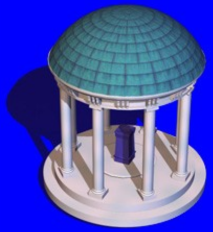
- **Collaboration is politically correct and fashionable.**

Collaboration and Telecollaboration

- Collaboration is politically correct and fashionable.
- Telecollaboration is even more so.

Collaboration and Telecollaboration

- Collaboration is politically correct and fashionable.
- Telecollaboration is even more so.
- Much telecollaboration R & D is technology-pushed, not application-pulled.



Collaboration and Telecollaboration

- Collaboration is politically correct and fashionable.
- Telecollaboration is even more so.
- Much telecollaboration R & D
  is technology-pushed, not application-pulled.
- We need far more understanding of collaboration.

Design Collaboration

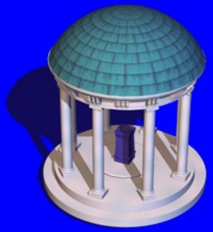
- Real design is always more complex than we imagine.
  - E.g., fixtures for parts, tooling limitations, assembly

Design Collaboration

- Real design is always more complex than we imagine.
  - E.g., fixtures for parts, tooling limitations, assembly
- Real design is hard to change — Design Change Control

Design Collaboration

- Real design is always more complex than we imagine.
- Design change control
- The cleaner the interfaces, the fewer errors.
  - Errors and rework are the big cost components.
  - Hence, *constrained* collaboration is most productive.



Design Collaboration

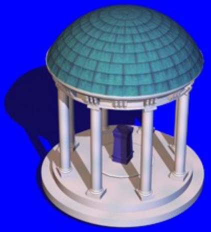
- Real design is always more complex than we imagine.
- Design change control
- The cleaner the interfaces, the fewer errors.
- Collaboration is no substitute for “the dreariness of labor and the loneliness of thought.”

When Does Collaboration Help?

- Determining needs from users
  - More minds —> more diverse questions

When Does Collaboration Help?

- Determining needs from users
- Conceptual exploration — radical alternatives



When Does Collaboration Help?

- Determining needs from users
- Conceptual exploration — radical alternatives
- *Not* conceptual design nor detailed design
  - Observe the great works of the human mind

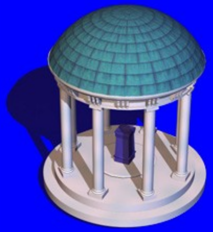
When Does Collaboration Help?

- Determining needs from users

- Conceptual exploration — radical alternatives

- *Not* conceptual design nor detailed design

- Design reviews
  - Especially with different expertise
  - Need and exploit richer graphical representations



III. Great Designs

Fan Clubs	No Fan Clubs
Fortran	COBOL
VM/360	OS/360
Unix, Linux	Microsoft NT
Pascal	Algol
C	PL/I
Macintosh	PC
APL	Ada

Product Processes

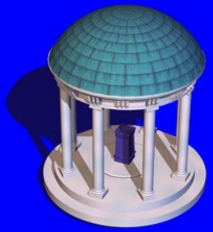
- Within- vs. outside product-process;
  What are product procedures for?

Product Processes

- Within-product-process vs. outside-produc
  What are product procedures for?

- How to do great design *within* a prod

- How to make a product process than
  rather than inhibits, great designs?



Great Designs Come From Great Designers

- How does one do great designs *within* a pr
- How to make a product process than encou rather than inhibits, great designs?
- Where elitism is proper
- Entrust design to a chief designer

Where Do Great Designers Come From?

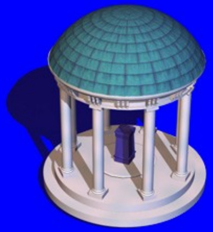
- We have to grow them *deliberately*.
  - Recruit for design brilliance, not talk sk
  - Make the dual ladder real and honorabl
  - Career planning and mentoring, as for m
  - Planned experiences, studies, and rotati

Where Do Great Designers Come From?

- We have to grow them *deliberately*.

- We have to manage them *imaginativ*

  - The John Cocke story

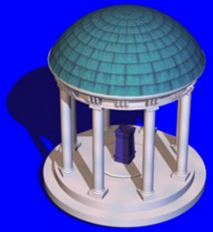


Where Do Great Designers Come From?

- We have to grow them *deliberately*.
- We have to manage them *imaginatively*
- We have to protect them *fiercely*.
  - From managers
  - From managing

Growing Yourself as a Designer

- Design lots of things, and keep a notebook.
  - Da Vinci's *Notebooks*
- Reflect in writing on your design experiences.
- Study other documented designs.
  - Write reviews of tools, software, video games, etc.
  - St. Paul's



The Great Designer

- **“If you want to see his monument, look around.”**
- **Some handiwork! SOD, hemoglobin, human visual system, earth as a life incubator**

The Great Designer

- “If you want to see his monument, look around.”
- Some handiwork! SOD, hemoglobin, human visual system, earth as a life incubator
- Good programmers don’t write sorts;

  they write sort generators.

The Great Designer

- "If you want to see his monument, look around."
- Some handiwork! SOD, hemoglobin, human visual system, earth as a life incubator
- Good programmers don't write sorts; they write sort generators.
- Human characteristics: morality, failure, guilt, urge to atone, desire to worship
- The knowledge that matters most!